AD-A258 653

||||||||||||||||||||

Ultrafast dynamics of quantum well lasers - ultimate potential for high speed modulation

Annual report , Sept. 1992

DTIC
ELECTE
DEC 22 1992
S   E   D

Kam Y. Lau

Department of Electrical Engineering and Computer Sciences

University of California

Berkeley, CA 94720

92-32343

||||||||||||||||||||

In the past year, we have concentrated our activities on obtaining a fundamental understanding of the role of carrier transport in quantum well lasers in their high speed modulation characteristics. For the past decade, it has been assumed that such transport effects are too fast to be of substantial consequence. Not until the past year did we begin to understand that intrinsic quantum capture of carriers into the quantum well, which occurs on a sub-picosecond time scale, has a severe effect on the modulation of quantum well lasers in the tens of gigahertz range. The effects are particularly severe in lower dimensional quantum materials. Through a combination of experimental and theoretical studies we are uncovering the physics behind these effects.

We extracted the intrinsic gain compression coefficients in tensile-strained 1.55 μm single quantum well lasers using an optical injection method. Lasers operating in the first and second quantized states are used. An explicit linear dependence of nonlinear gain on the differential gain is obtained from these measurements. These results are quantitatively compared to a model involving carrier transport in and out of the quantum well.

To further understand the quantum capture and escape process, analytic expressions for carrier *capture* and *escape* currents into quantum well are derived. We find that the *escape* rate

1

can be as large as the *capture* rate under typical operating conditions in quantum well lasers so that the damping and inertia of the relaxation oscillation are significantly increased in these lasers. The implication on the limitation in modulation bandwidth of quantum well lasers and its dependence on the quantum well structure are discussed.

Using the above results, we derived an intrinsic equivalent circuit of quantum well lasers, with the capture of carriers into the quantum well being taken into account. This type of equivalent circuit is essential in dealing with practical modulation of laser diodes. Several qualitative features in the modulation response and the device impedance are revealed. The dependences on the carrier capture and escape rates are discussed.

Furthermore, we investigated the combined effects of carrier diffusion in the Separate Confinement Heterostructure region and quantum capture into the Quantum Well must be considered together when evaluating the limits on the modulation bandwidth of quantum well lasers, despite the fact that quantum capture is considerably faster than carrier diffusion. The importance of quantum capture may be observed by noting that the modulation bandwidth is adversely affected even for quantum capture times as short as 0.2*ps*, *or* if the ratio of the quantum capture time to quantum escape time is large (>0.01). Therefore, the bandwidth limitation may be caused by electron transport rather than hole transport since quantum capture of holes is faster than that of electrons.

The above results are contained in the following published, refereed journal articles:

"Gain compression in tensile-strained 1.55μm quantum well lasers operating at first and second quantized states", Appl. Phys. Lett., 60, 1794 (1992).

"Quantum capture and escape in quantum well lasers - implications on direct modulation bandwidth limitations", Photonics Tech. Letts., 4, 428 (1992).

"Intrinsic equivalent circuit of quantum well lasers", Photonics Tech. Letts., 4, 528 (1992).

"On the effect of carrier diffusion and quantu capture in high speed modulation of quantum well lasers", Appl. Phys. Lett., 61, 752 (1992).

Copies of the above articles are attached with this report.

2